DOCUMENT RESUME

ED 315 283 SE 051 163

AUTHOR Vetter, Betty M.
TITLE Replacing Science and Engineering Faculty in the 1990s. Occasional paper 89-4.
INSTITUTION Commission on Professionals in Science and Technology, Washington, DC.
PUB DATE Dec 89
NOTE 31p.; Adapted from Presentations at the Conference on Undergraduate Research at Carleton College (Northfield, MN) and the Task Force of Engineering Deans, American Society for Engineering Education (Washington, DC). Black type on red paper (3 pages) illegible.
AVAILABLE FROM Commission on Professionals in Science and Technology, 1500 Massachusetts Ave. N.W., Suite 831, Washington, DC 20005 (subscription series, calendary year $55.00 non-member, $40.00 member; single paper $20.00 non-member, $15.00 member).
PUB TYPE Viewpoints (120) -- Statistical Data (110)

EDRS PRICE MF01 Plus Postage. PC Not Available from EDRS.
DESCRIPTORS *College Faculty; Engineering; *Engineering Education; Faculty; *Faculty Recruitment; *Foreign Students; Higher Education; *Minority Groups; Science Careers; Science Education; Statistical Data; *Supply and Demand

ABSTRACT

A future faculty shortage problem in science and engineering areas is discussed. The trends of enrollment of undergraduate and graduate student by field are described. Data on current faculty, faculty vacancy rates, and faculty characteristics are presented and discussed. The characteristics include the citizenship, age, sex, and ethnic background of faculty members. Future demands are discussed by field and institution. It is concluded that time to institute a policy change is running out for the United States. Now is the last possible moment to begin to recruit U.S. students (and, particularly women and minority students) to prepare for faculty careers in the 1990s and beyond. Statistical data are provided for many variables. Lists 22 references. (YP)

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REPLACING SCIENCE AND ENGINEERING FACULTY IN THE 1990s

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by

Betty M. Vetter

Adapted from Presentations at

Conference on Undergraduate Research at Carleton College
Northfield, Minnesota

and

Task Force of Engineering Deans
American Society for Engineering Education
Washington, D.C.

Occasional Paper 89-4

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SCIENCE AND ENGINEERING FACULTY

IN THE 1990s

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Acknowledgements

Figures 3 and 7 are from **Report of the NSB Committee on Foreign Involvement in U.S. Universities,** NSB 89-80, National Science Board of the National Science Foundation.

Figure 4 is from "Who Are We? Engineering and Engineering Technology Faculty Survey, Fall 1987, Part I", by Paul Doigan and Mack Gilkeson, **ENGINEERING EDUCATION,** October 1988.

Figure 23 is from "Future Scarcities of Scientists and Engineers: Problems and Solutions," Working Draft dated April 25, 1989, prepared by the National Science Foundation.

All remaining figures were prepared by Richard C. Vetter utilizing data from the source noted in the figure, and published in December, 1989 in the eighth edition of **Professional Women and Minorities: A Manpower Data Resource Service,** by the Commission on Professionals in Science and Technology.

REPLACING SCIENCE AND ENGINEERING FACULTY IN THE 1990s

The past decade has been a period of generally low and stable demand for new faculty, except in schools of engineering and business, where faculty increases have been mandated by rising student enrollments. Thus, with relatively few opportunities for academic employment, the number of graduate students in the sciences stayed relatively constant, and the faculty got older. Despite increased demand for engineering faculty, the demand for baccalaureate engineering graduates was so good, and the starting salaries relatively so high, that a diminishing number of American baccalaureate graduates went on to graduate school. The openings they left were filled with foreign students, eager for a graduate education in an American university. By 1987, foreign students comprised 45 percent of all graduate students in engineering, 43 percent in mathematics, and 41 percent in computer science in U.S. doctorate-granting institutions (NSB 1989).

PhD production in science and engineering, taken as a whole, peaked in 1973, dropped slowly through 1979 and has been rising during the 1980s, averaging about 17,000 new PhDs per year since 1970. While the number of degrees in the physical sciences and engineering has risen substantially since 1980, most of the increases until 1987 were in foreign citizens.

Meantime, the number of Americans of college age started to drop in 1980, and more and more of the potential students in this dwindling pool of tomorrow's young American adults are reaching college entry level without the high school preparation essential to a major in science or engineering. The racial composition of this shrinking group of young people also is changing quite rapidly. More of our freshman-age students each year are poor, black and/or Hispanic, and American colleges have a poor track record in attracting and educating young men and women with these backgrounds into science and engineering.

Since today's undergraduate and graduate students are tomorrow's faculty replacements, it is more than time to stop and take stock of the potential pool of graduate students for the coming decade. They are the teachers and research mentors of the students of the next century, so that what happens now and over the next few years will reverberate not only through the 1990s, but for decades to come.

WHO IS IN THE PIPELINE

Bachelor's degrees are a necessary precursor to doctorates - a requirement for most faculty slots. But just as we enter the beginning of a period of increased demand for doctorates, both as faculty replacements and researchers in industry and government, the number of bachelor's graduates is dropping in the natural sciences and engineering. This, in turn, provides a smaller base for PhD production among American students.

Even if for no other reason, there will be fewer baccalaureate graduates in engineering and science through the nineties than in the eighties because of the drop in the size of the college age population. The number of 22 year olds - the typical age for graduation, peaked in 1982, and will bottom out in 1996 before starting to rise again (fig. 1).

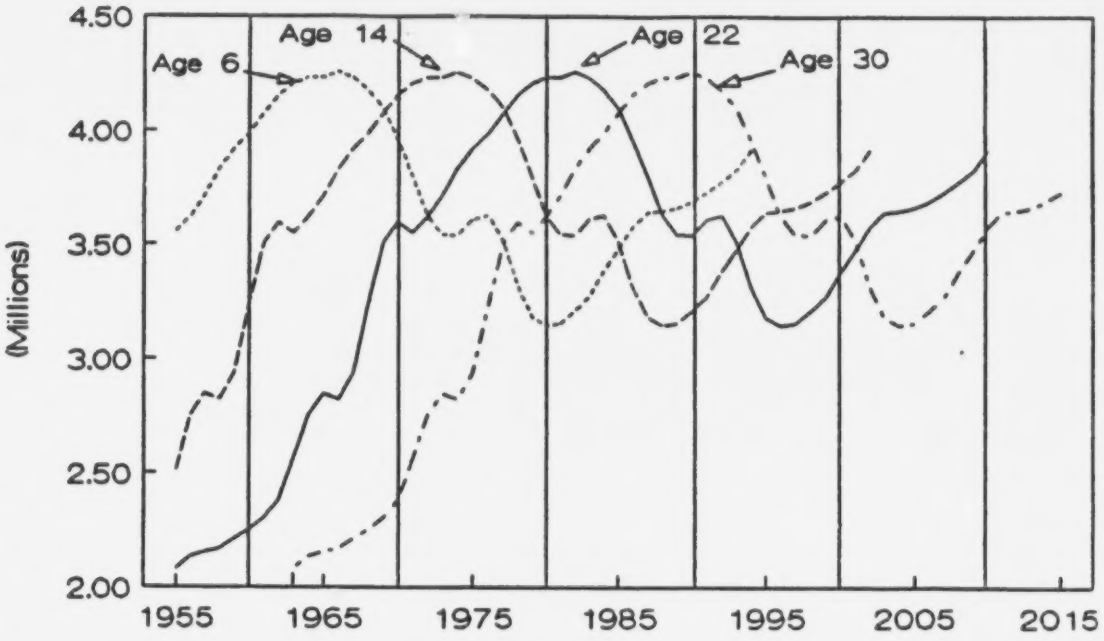

Figure 1. The Shifting Population Age Groups. Data Source: Census Bureau Record of Live Births.

In addition to having a shrinking college age population the percentage of freshmen who are choosing to major in any of the natural science or engineering fields has been dropping since 1982 (fig. 2).

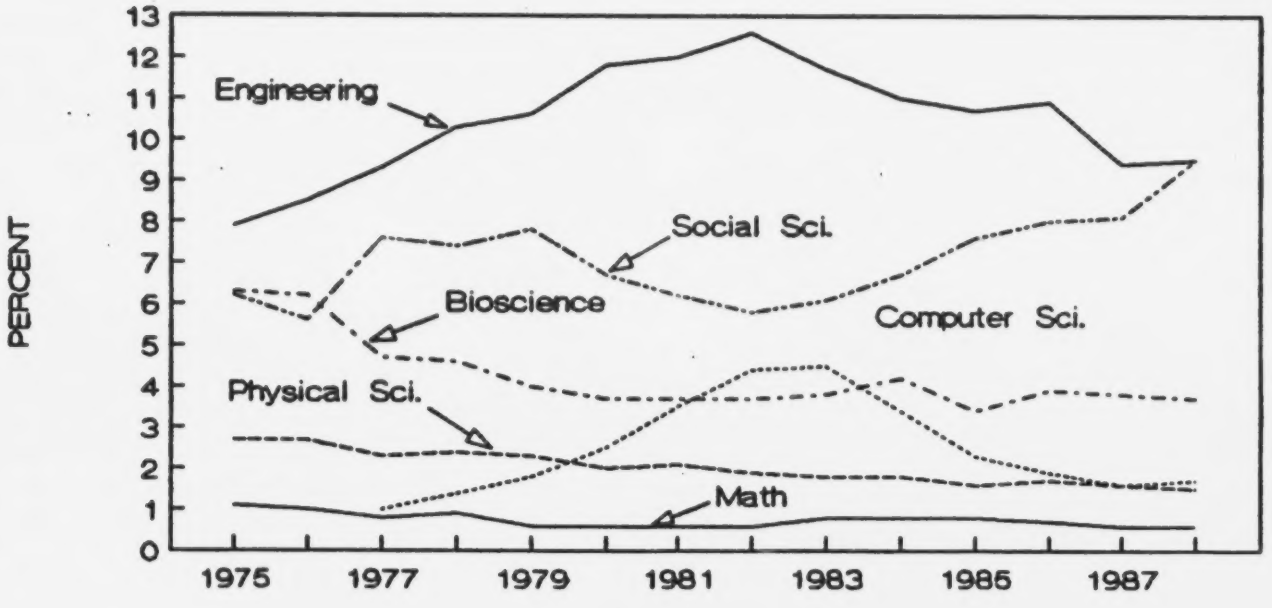

Figure 2. Freshman Plans for Science and Engineering Majors, 1975-1988. Data Source: Cooperative Institutional Research Program of the American Council on Education and UCLA

The past two decades have been a period of shifting funding priorities for graduate education in science and engineering, with growth in some areas, and a severe decline and then resurgence in others. Fellowships have declined substantially, and research funds used to hire graduate research assistants cannot readily be distinguished from the rest of the research funds.

The percentage of foreign students has increased substantially in all science and engineering fields during the past decade (fig. 3).

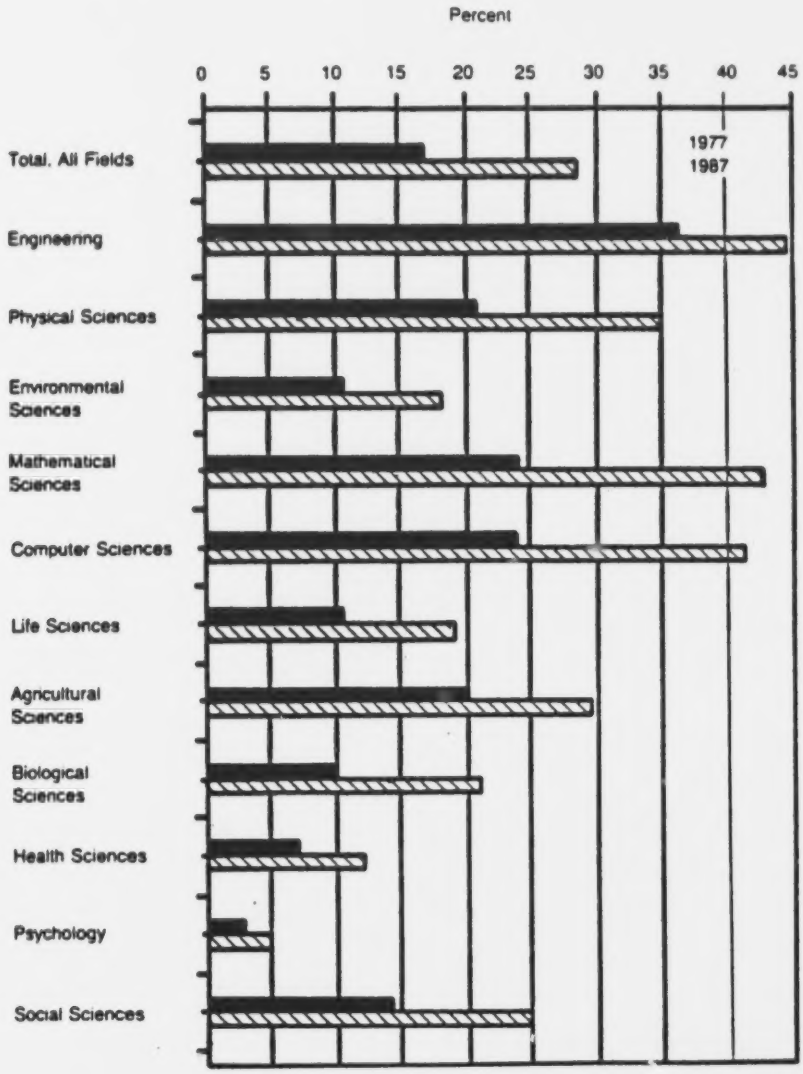

Figure 3. Foreign Full-Time Graduate Science/Engineering Enrollment in Doctorate-Granting Institutions by Field, Fall 1987. Source: National Science Board, 1989

Doctorate awards in physics, chemistry, mathematics and engineering per thousand 30-year-old U.S. citizens have plummeted since 1971, and no present evidence indicates an increase in the future. The increase in doctoral awards in these fields in 1988 coincides with the peak of American thirty-year-olds, whose numbers will drop by more than one million by 2005, when the need for faculty replacements will be substantially larger than now.

PRESENT FACULTY PICTURE

Faculty Vacancy Rates

In engineering, there has been a shortage of qualified faculty to fill funded positions for at least a decade. For the past several years, the American Society for Engineering Education has made periodic surveys of engineering and engineering technology faculty to find out the degree of difficulty experienced by engineering schools in filling their faculty positions, and how many authorized but unfilled slots they have. This latter number has decreased since the first survey in 1980, when almost ten percent of all authorized, full time faculty positions in engineering, were unfilled (Doigan et al 1988). By fall 1987, the proportion had dropped to 7.2% (fig. 4).

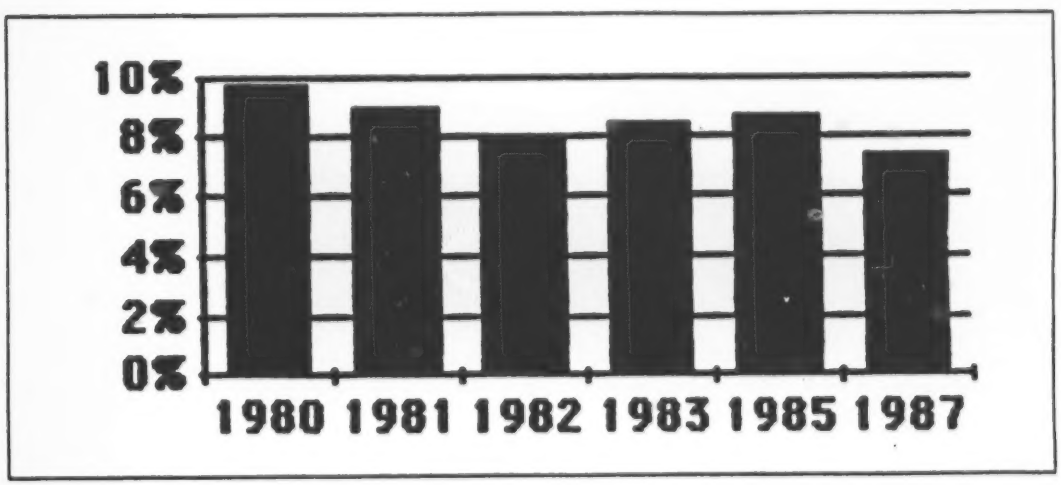

Figure 4. Engineering Faculty Shortage 1980 - 1987, Based on Unfilled, Authorized Full-time Faculty Positions in Engineering. Source: Doigan and Gilkeson, "Who Are We? Engineering and Engineering Technology Faculty Survey Fall 1987, **Engineering Education**, October and November 1988.

Of course, some engineering fields have more vacancies than others, with about one fourth of all reported vacancies in 1987 being in electrical/ electronic engineering. The highest proportional rates were in computer science and computer engineering, followed by industrial engineering, both with more than 10% of authorized full time faculty positions vacant. Vacancies continue to be concentrated at the entry level, with one sixth of all authorized positions for assistant professors in engineering unfilled.

Nonetheless, despite the continuing vacancies in authorized positions, 44 percent of the schools reported that recruitment was easier in fall 1987 than in the previous year.

Faculty Characteristics

Citizenship

Citizenship is an important parameter among engineering and computer science faculty, and is becoming an increasing factor in some of the physical and mathematical sciences.

Data from the National Science Foundation (NSF 1987) indicate that a substantial proportion of the hiring of inexperienced engineering faculty in recent years has consisted of foreign citizens. This is not surprising, since more than half of all PhD awards in engineering from U.S. universities since 1980 have been earned by foreign citizens (fig. 5).

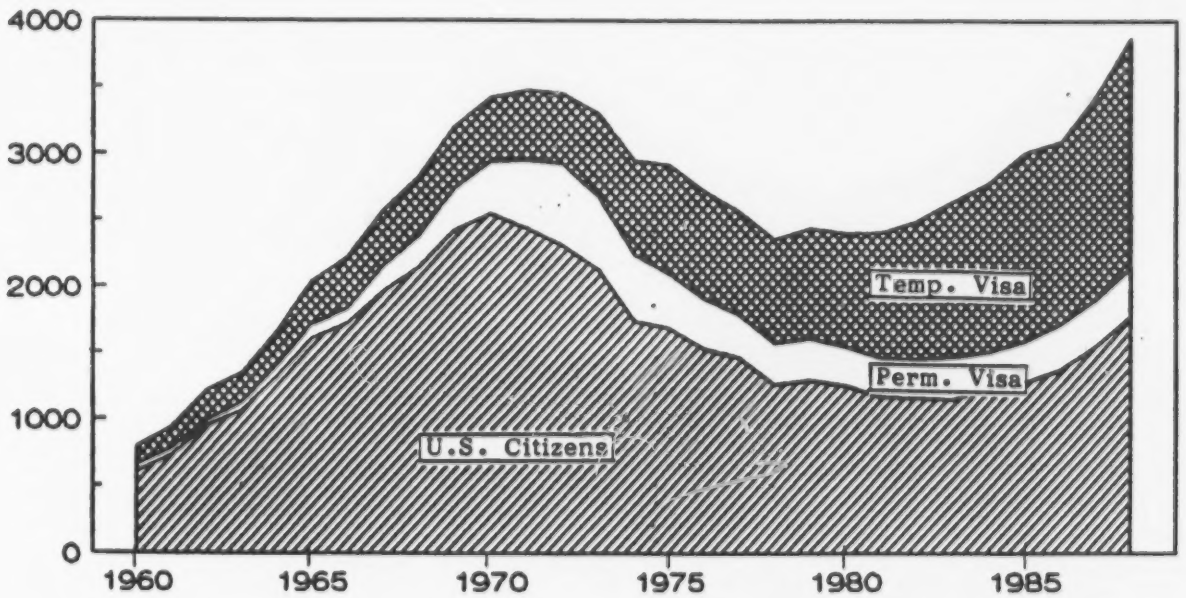

Figure 5. Citizenship of Engineering Doctoral Recipients, and Visa Type of Foreign Recipients, 1960-1988. Data Source: National Research Council, **Summary Report 1985** through 1988: **Doctorate Recipients from United States Universities**

Although the addition of foreign graduates to American faculties provides many benefits, it also introduces problems, particularly when the proportion of new hires at the assistant professor level who are foreign citizens reaches half the total. By 1983, that had occurred. Although the percentage dropped slightly in 1985, it remained above 50 percent (fig. 6).

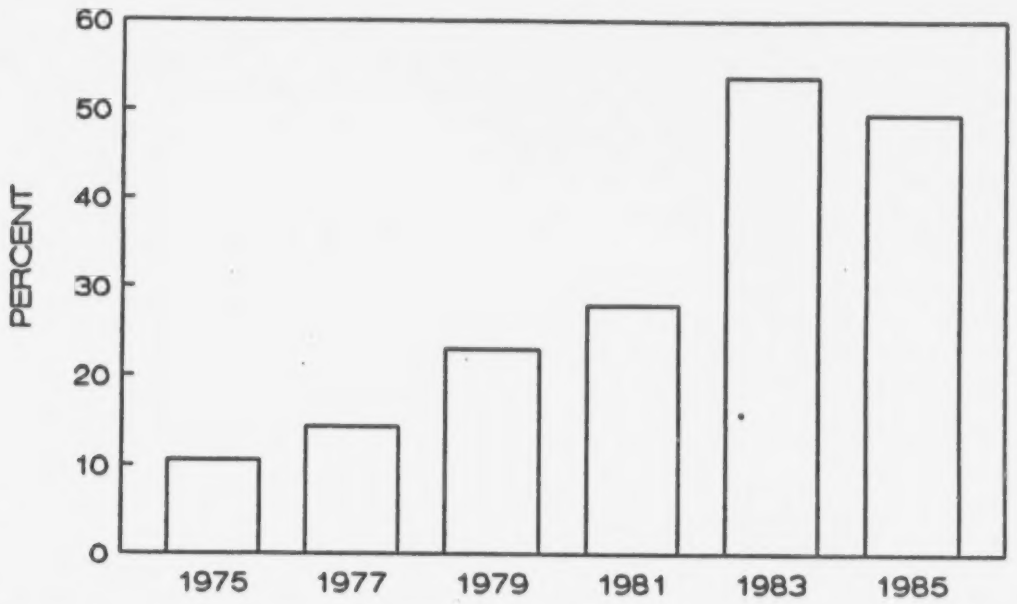

Figure 6. Foreign as a Percentage of All Assistant Professors in Engineering age 35 or less. Data Source: National Science Foundation, **Foreign Citizens in U.S. Science and Engineering: History, Status and Outlook**, 1987.

Although the high concentration of foreign faculty among the young assistant professors was not duplicated at higher ranks or in other fields, the availability of American engineering and science doctorates for faculty positions was too little to fill faculty positions, so that about ten percent of all engineering faculty in PhD institutions were foreign citizens by 1986, and about one third of them were still holding temporary visas.

Although notable for having the largest numbers of foreign faculty, engineering was not unique in hiring foreign faculty, including large numbers with temporary visas (fig. 7).

One difficulty involving the use of large numbers of foreign graduates as faculty in American universities is that it cannot be assumed that they will wish or be allowed to remain in the United States.

Even those who obtain immigrant status may decide to return home when conditions and opportunities in their homelands have changed. For example, a liberalized political environment and a surging economy in South Korea have encouraged thousands of expatriates, many of them academic scientists and engineers, to come home.

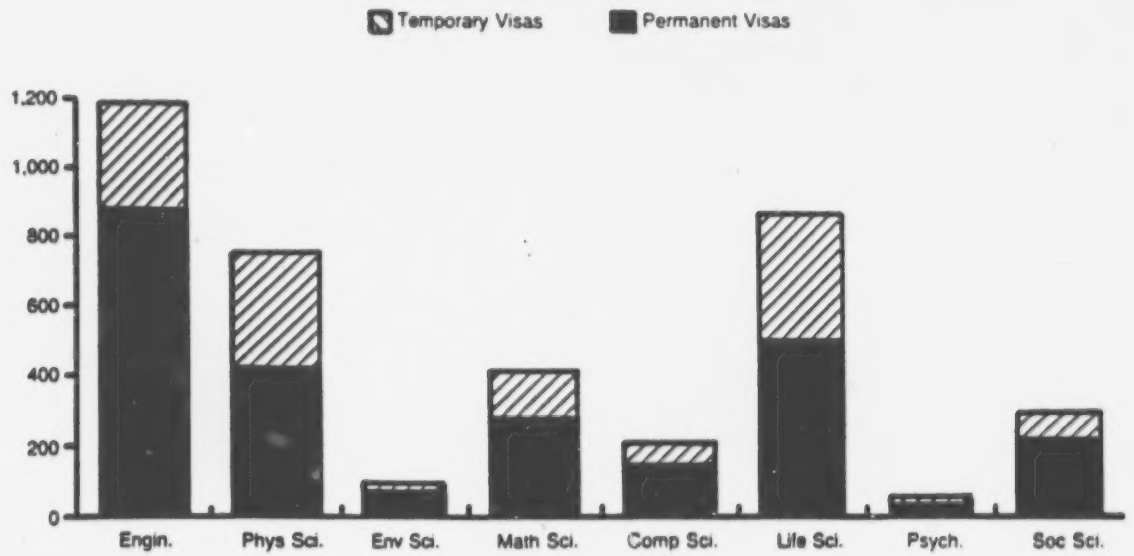

Figure 7. Foreign Faculty by Field and Visa Type, 1986. Source: National Science Board 1989.

Since 1980, about 20,000 former inhabitants have relinquished permanent residence overseas to return home. The three year old South Korean Postech now has 155 faculty members, 243 graduate students and 744 undergraduates (Gittlesohn, 1989). Eighty seven percent of the Postech faculty members earned doctorates at American universities. Many spent years in postdoctoral or teaching positions at major American institutions.

South Korea is not alone in opening new opportunities for former citizens who earned engineering and science degrees abroad and stayed to work. Many highly educated natives of Japan, India, Singapore, Taiwan and other countries with rapidly emerging science and technology sectors have been returning to their original countries for jobs in academe, government and industry. Thus, it cannot be assumed that foreign faculty members in American institutions will remain on American faculties, even when they have acquired permanent status.

Some of the foreign PhD recipients have already obtained permanent visas by the time of the degree award (fig. 5). In addition, in past years, about half of the remaining foreign doctorate recipients in engineering ultimately stayed here and became a part of the U.S. work force, even though some are now returning to their own counties.

These foreign additions to our American melting pot make inestimable contributions to our nation, and particularly to our universities - as graduate students, as teaching and research assistants, and as faculty researchers and teachers. They are also the source of some problems.

Researchers from the Institute for International Education and Washington University in St. Louis studied the effect of foreign students in American engineering schools in a 1985 survey of departmental chairs and faculty in engineering (Barber et al, 1988). The significant finding of their study is that foreign graduate students are now essential to the operation of both training and research programs in U.S. engineering schools.

Foreign faculty and teaching assistants bring many benefits to U.S. education, in engineering and in other fields as well, but the high proportion of foreign students and graduates in engineering and in other science areas also presents problems. U.S. dependency on foreign students and graduates is itself a problem, because, for several reasons, the U.S. cannot count on continuing to keep here and utilize the recent high proportion of foreign students.

In addition to the loss of those who decide to return to their native countries after a protracted stay in the United States, those still on temporary visas may be forced to leave before they can obtain permanent visa status because recent American laws limit the renewal of temporary work permits.

The American Congress has been ambivalent about almost every facet of the admission and utilization of foreign students. In a move apparently designed to discourage foreign students, one provision of the 1986 U.S. tax law, later revoked, imposed income taxes on foreign scholarships, in addition to limiting deductions available to foreign students.

At the same time, several American Congressional Committees have recognized that foreign students and graduates have become an essential part not only of American engineering schools but of many American industrial research laboratories. While one Committee of the Congress will put difficulties in the way of a foreign graduate seeking a change in visa status in order to accept U.S. employment, another will open a gate, even if it is unnecessarily weighted down with difficult latches.

Age

The present stock of American doctoral scientists and engineers passed a significant milestone in 1987, according to the National Science Foundation, with over half of its members being 45 years old or older (NSF 89-305). About a quarter of them were 55 years old or older. The oldest faculty is in physics; the youngest in computer sciences (fig. 8).

This aging effect reflects the significant increase in science and engineering doctorates following World War II, peaking in 1972; and the subsequent decline of 14 percent in the sciences and 35 percent in engineering in doctorate production among American citizens and permanent resident non-citizens. Additionally, the age of new Ph.D. recipients in science and engineering has risen, with the median elapsed time from baccalaureate to doctorate rising from 7.4 years in 1977 to 8.5 years in 1987.

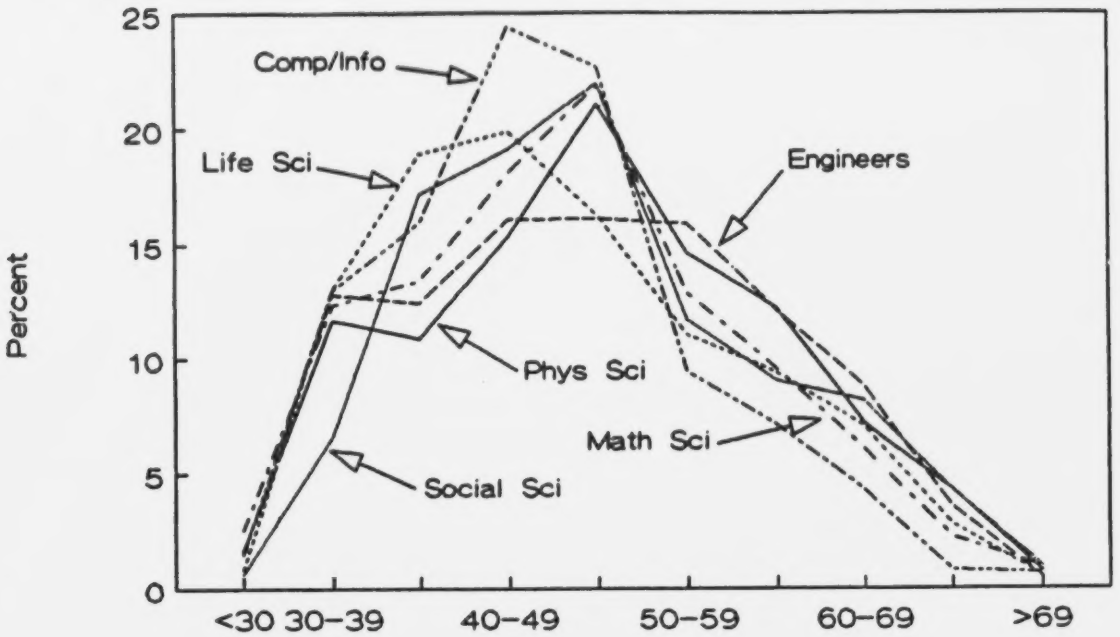

Figure 8. Age of Doctoral Faculty in Science and Engineering in 1987. Data Source: National Science Foundation, **Characteristics of Doctoral Scientists and Engineers, 1987**

A far greater proportion of the senior faculty will be reaching retirement age in the next ten years than was true in the previous decade, (NSF 1977 and 1987), and the number of replacements needed to maintain a faculty about the same size as now also will be much larger than in the past decade. More than half of the current doctoral faculty in science and engineering are over age 44; more than a third are over age 50, and a fourth of teaching faculty will reach age 65 by 1995 (fig. 9). The computer science and life science faculties are generally younger than the other science and engineering faculties.

The annual rate of retirement among this group of about 451,000 individuals rose from about 0.5 percent between 1977-79 to 0.8 percent during 1985-87. This increase raised the proportion of retirees in the doctoral population from 3.1 to 4.8 percent.

By degree field, six to eight percent of doctorate holders in the physical and social sciences and in chemical engineering retired during this interim, compared with three to four percent of doctorates in the mathematical and environmental sciences, psychology, and in aeronautical, electrical and mechanical engineering. Among those in computer science, a relatively new field, no retirements were reported.

When the cap on faculty retirement by age 70 is eliminated in 1993, at what age will faculty choose to retire? Among doctorates retiring between 1985 and 1987, a small number were under 50, and individuals over age 69 accounted for about 15 percent, but the average age was 65, and about 87 percent were at least sixty.

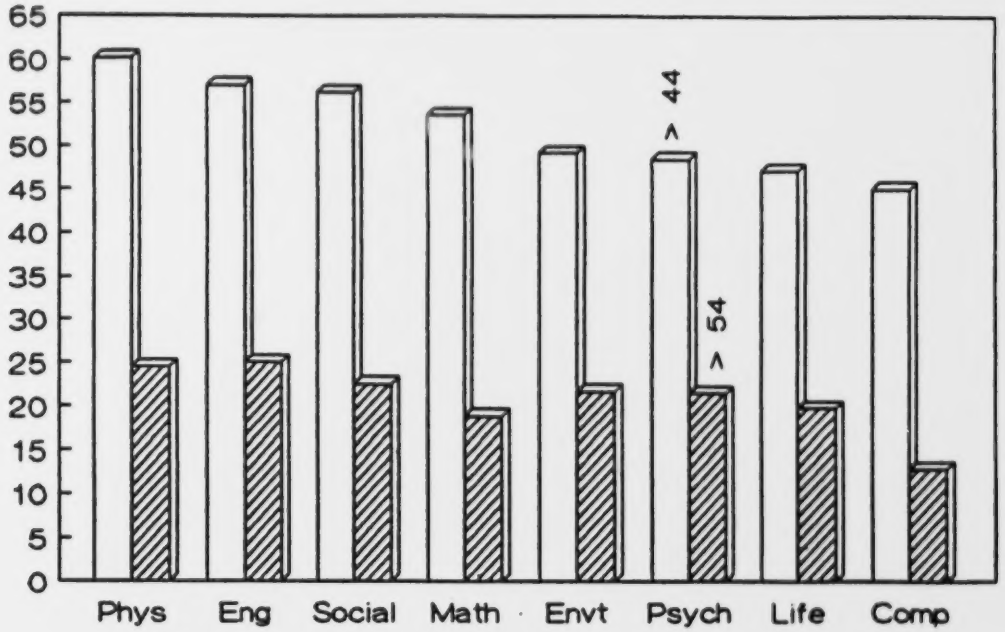

Figure 9. Percentage of Academic Doctoral Scientists and Engineers Older than age 44 and age 54 in 1987, by Field. Data Source: National Science Foundation, **Characteristics of Doctoral Scientists and Engineers, 1987**, 1989

Employment of doctoral scientists and engineers rose at an annual rate of four percent during the decade from 1977 to 1987, slowing in the latter half of the period, particularly in engineering. The increasing pace of retirements, however, which will continue to escalate through the coming decade, poses a significant problem of replacement as well as an excellent opportunity to those now entering or contemplating graduate school.

Throughout the decade between 1977 and 1987, about 95 percent of doctoral scientists and engineers were in the labor force, and the unemployment rate for this group remained at about one percent. Slightly more than half (52 percent) of all employed doctorates worked in educational institutions in 1987, with the proportion varying from 30 percent of computer/information specialists and 35 percent of engineers to 82 percent of mathematical scientists and 70 percent of social scientists.

What changed significantly was their age distribution. In addition to the substantial increase in the proportion above age 54, there was a decrease at the lower end of the age range, where about 12 percent of all doctoral scientists and engineers were under age 35 in 1987 compared with 21 percent in 1977. Nonetheless, the retirement flow of present faculty members out of higher education is expected to be remarkably smooth overall through the next two decades.

The age change was not limited to scientists and engineers. Between 1977 and 1987, the percentage of all arts and sciences faculty under age 40 fell from 42 to 22 percent, while the percentage over 49 rose by more than one third, from 27 to 39 percent.

Sex

A slow but steady increase in the number of women earning doctorates in science and engineering has also resulted in a small increase in the number of women faculty in these fields. But even by 1985, the proportion of women among engineering doctoral faculty was only two percent, and in the physical and math sciences, less than eight percent of doctoral faculty were women. As indicated in figure 10, by 1985 almost one in every five faculty in the life sciences and in the social and behavioral sciences was a woman. But given the fact that women make up half of the population and earn more than a third of the doctoral awards to American citizens in the combined science and engineering fields, their presence in the tenure-track faculty population is disproportionately small.

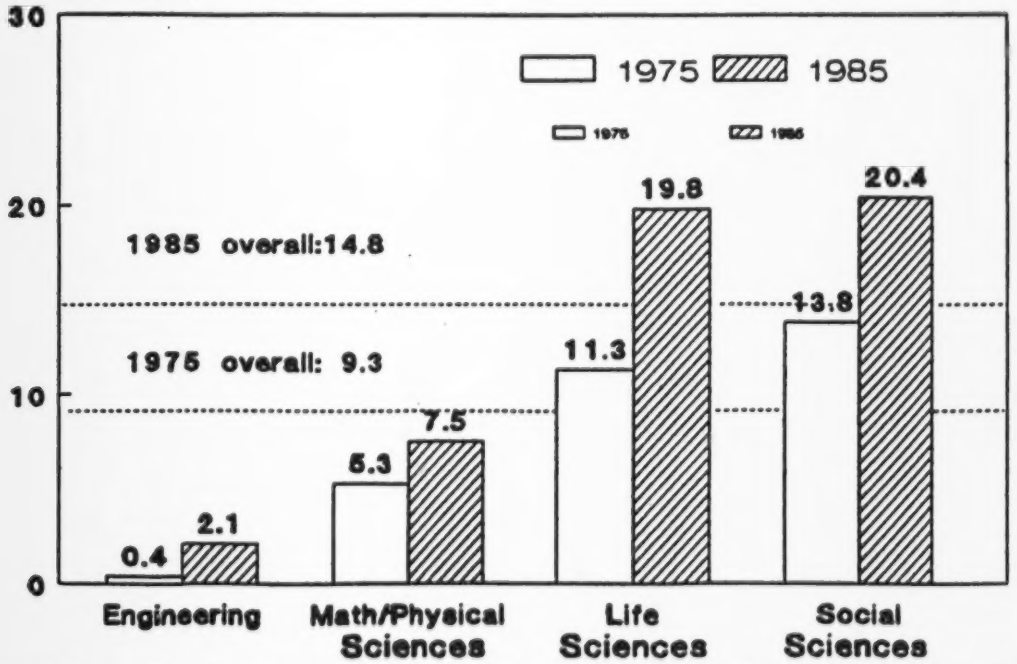

Figure 10. Percentage of Science and Engineering Faculty Who are Women, 1975 and 1985, by Broad Field Group. Data Source: National Science Foundation, **Characteristics of Doctoral Scientists and Engineers, 1975** and **1985**

By 1987, women were 2.4 percent of the faculty in engineering, 8.8% in the the math/computer science/physical science group, 21.9% in the life sciences and 23.2 percent in the social and behavioral sciences.

But current degree data offer little promise of significant increases in the number of women faculty over the next decade. At the bachelor's level, the proportion of women in the graduating class in engineering has levelled off at 15 percent after climbing steadily for a decade (fig. 11).

Significantly, a new survey of women engineering students found that although 80 percent said they wished they had more faculty female role models, only six percent indicated a strong interest to pursue an academic engineering career (Baum, 1989).

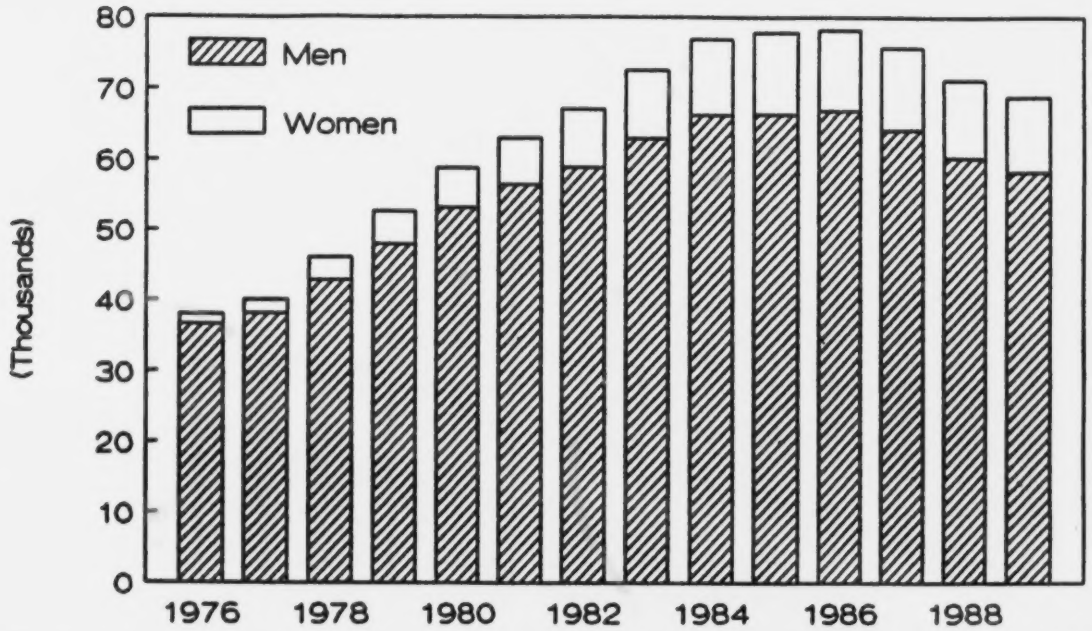

Figure 11. Men and Women Bachelor's Graduates in Engineering, 1976-1989. Data Source: Engineering Manpower Commission series of **Engineering and Technology Degrees 1976** through **1989**.

In the sciences, the number of women earning baccalaureate degrees turned down by 1987 in every major field of natural science (fig. 12), and their percentage of the total baccalaureate awards has levelled off or started to fall well before they reached parity, except in psychology and some of the social sciences.

At the doctorate level, American women earned 34 percent of the science and engineering doctorates awarded to U.S. citizens in 1988, but only 28 percent of all science and engineering PhDs awarded by American Universities that year (NRC 1989 in press) because foreign recipients are even less likely than Americans to be women! In the physical/math sciences and engineering, they earn fewer than 600 PhDs per year (now 12 percent of PhD awards to Americans) and in engineering, American women earned only 174 PhDs in 1988 - ten percent of the American graduates. At the present rate of increase, women do not appear to be the answer to any potential faculty shortages in either of these areas for several decades to come (fig. 12). However, one of the reasons no shortages are foreseen in the biological sciences is the rapid increase in doctoral degrees earned by women.

To some degree, utilizing foreign graduate students as teaching assistants, and foreign graduates as faculty also may work against efforts to increase the number of women faculty in engineering. The cultural backgrounds of the foreign students often clash with the American view that women are capable and worthy students and colleagues in science and engineering. Of course, all American faculty do not hold that view either!

Because engineering has both the largest proportion of foreign faculty and the smallest proportion of women faculty, American women students may have no place to turn for help when problems occur.

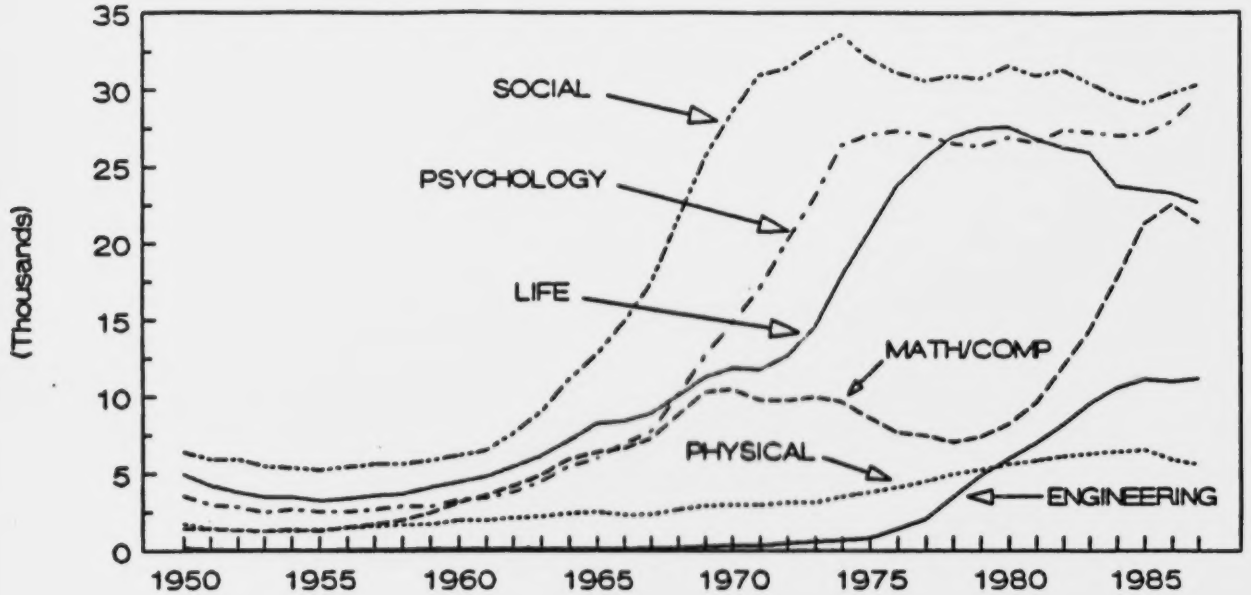

Figure 12. Women Science and Engineering Bachelor's Graduates by Field, 1950-1987. Data Source: National Center for Education Statistics Series of **Earned Degrees Conferred by U.S. Colleges and Universities.**

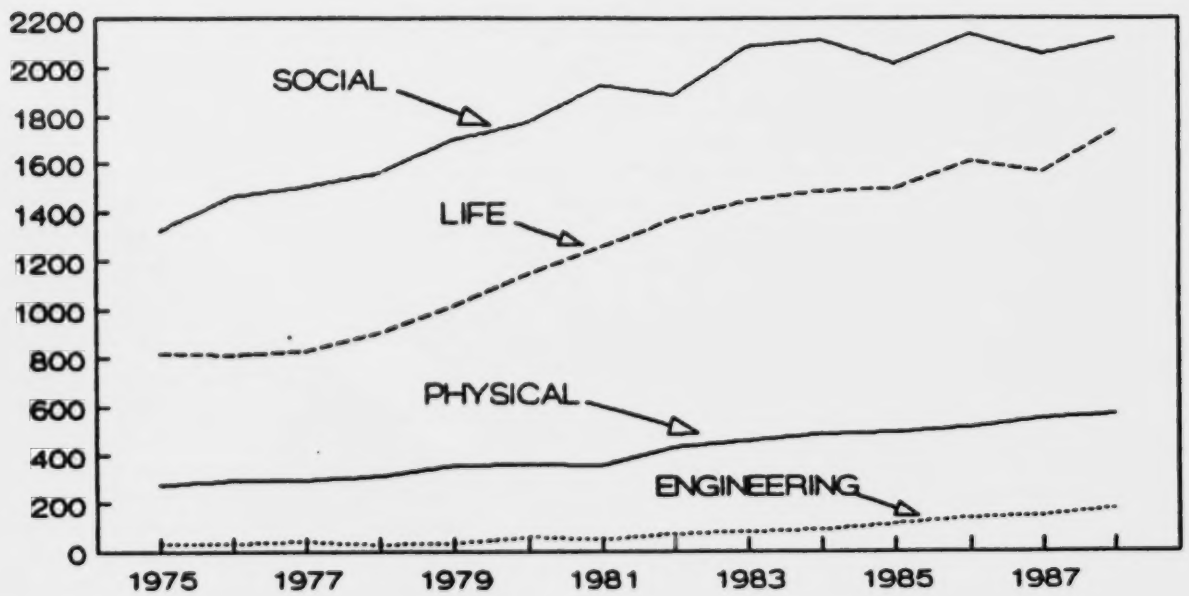

Figure 13. Number of Doctoral Awards in Science and Engineering Awarded to American Women, by Broad Field, 1975 - 1988. Data Source: National Research Council

American Racial/Ethnic Minorities

The number of non-Asian American minorities enrolled in science, and particularly in engineering graduate programs leading to the doctorate, is miniscule. Although they make up one fourth of the age-30 population, blacks, American Indians and Hispanics combined earned only 66 engineering doctorates in 1988, only 1.8 percent of the total engineering doctorates awarded by American Universities that year. There has been a slight increase over the decade, and a notable increase in 1988 (fig 14). In engineering, white women, as well as black, Hispanic and American Indian men and women, are a distinct minority.

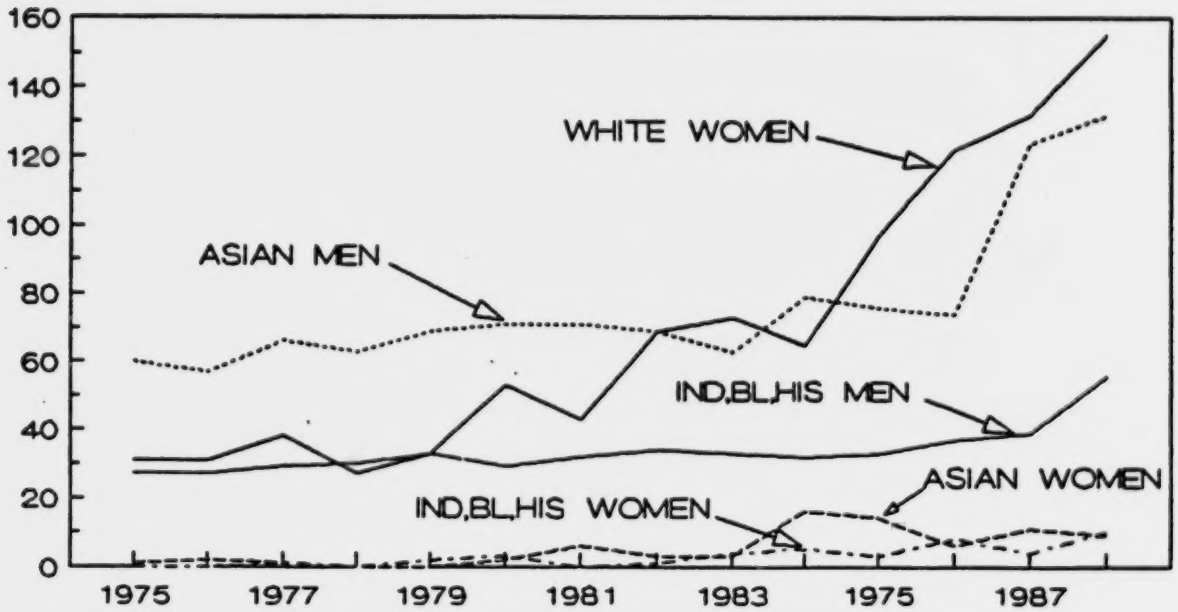

Figure 14. PhDs in Engineering Awarded to American Minorities, by Sex,1975-1988. Data Source: National Research Council, **Summary Report 1975** through **1988: Doctorate Recipientds from United States Universities**

The numbers of minority doctorates in the physical sciences (fig. 15) and the life sciences (fig. 16) are so small that even if all American minority doctorates in these fields accepted academic positions, American higher education would still contain only a smattering of minority faculty.

Black faculty members in the sciences, even including the social sciences, are largely invisible. They constitute less than one percent of engineering faculty, and less than 3 percent of physical science faculty. Further, except in the social sciences, the increase over the past decade is insignificant (fig. 17). Here the problem of lack of role models is dramatically underlined. How can growing numbers of minority young people learn that research is rewarding? that science and engineering are viable areas of study and work? that people like them find interesting careers in these fields and are in great demand?

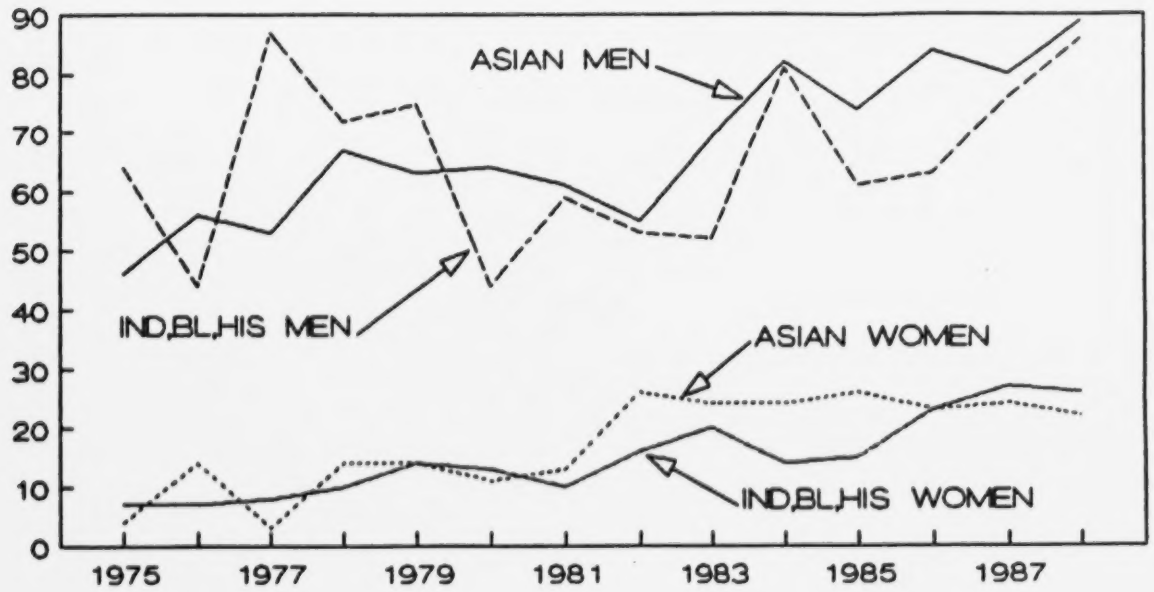

Figure 15. PhDs in Physical Sciences Awarded to American Minorities, by Sex, 1975-1988. Data Source: National Research Council **Summary Report 1975** through **1988: Doctorate Recipients from United States Universities**

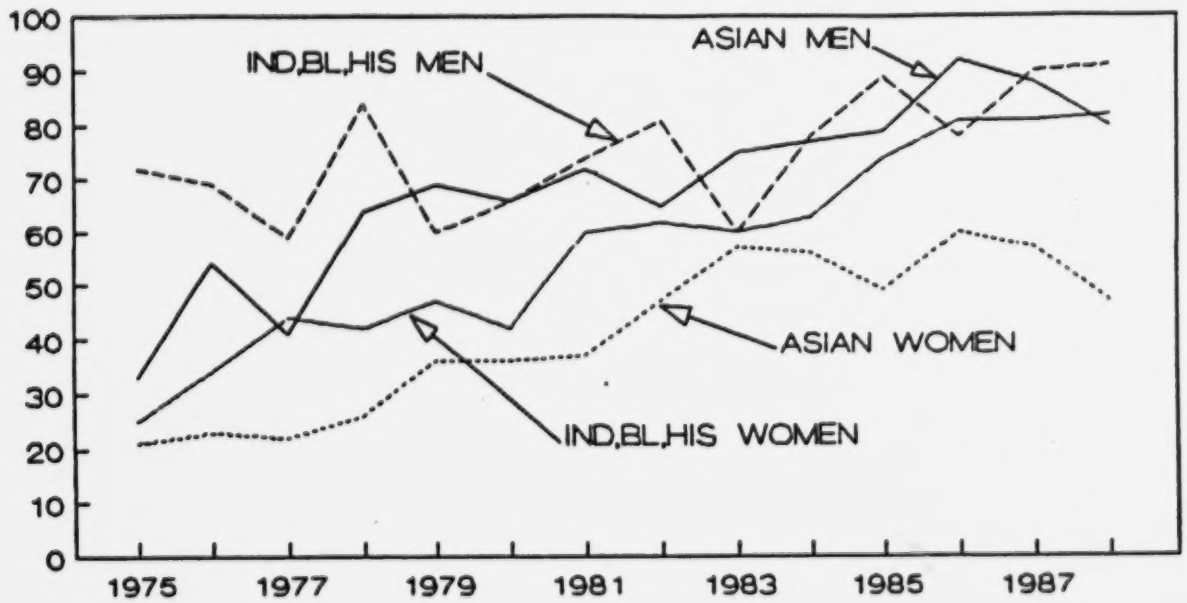

Figure 16. PhDs in Life Sciences Awarded to American Minorities, by Sex, 1975-1988. Data Source: National Research Council **Summary Report 1975** through **1988: Doctorate Recipients from United States Universities**

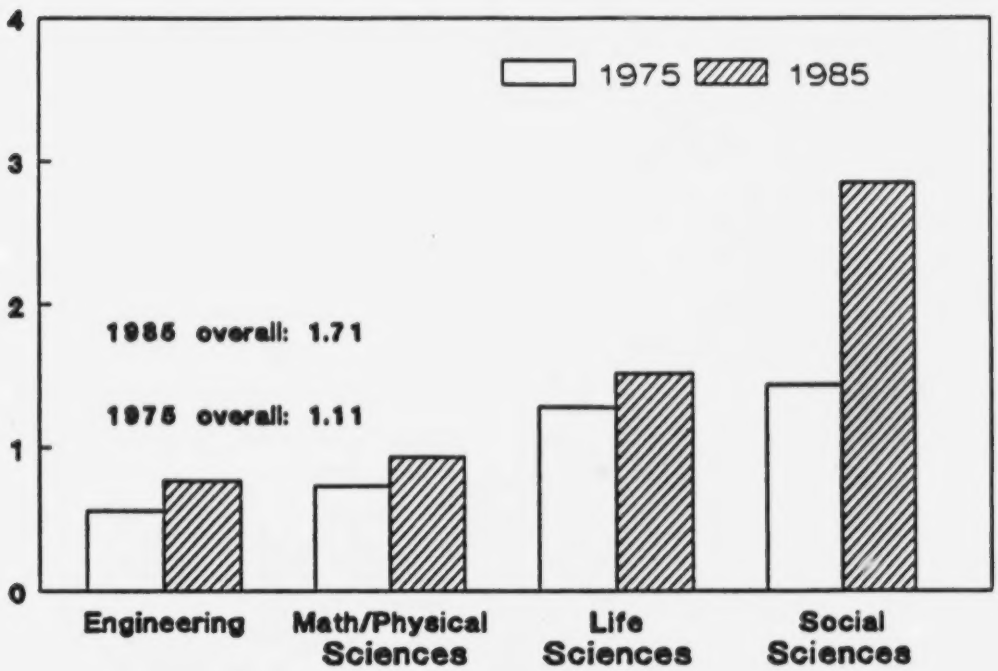

Fig. 17. Percent Blacks on U.S. Science and Engineering Faculties, 1975 and 1985. Data Source: National Science Foundation, **Characteristics of Doctoral Scientists and Engineers 1975** and **1985.**

Asian Americans, although apparently "overrepresented" among engineering and physical science doctorates relative to their proportion in the U.S. population, actually are almost all foreign-born. Among Asian science and engineering PhDs in the U.S. labor force in 1985, 92 percent were born outside the United States (NRC, special tabulation 1987). Among all U.S.-born scientists and engineers in the doctoral population that year, only 0.6 percent were of Asian ancestry - less than half of Asian American representation in the general American population. U.S. Asians have earned as much as 4.5 percent of natural science and engineering doctorates in 1987, but the proportion fell in 1988 (fig. 18). Among all doctoral awards earned by Asians, however, most recipients are foreign citizens (fig. 19).

FUTURE DEMAND

The possibility that our supply of doctoral engineers will be insufficient and will need to be supplemented from one source or another is dependent on the level of demand. Although we are unable to determine with certainty the level of future demand, considerable thought has been given to probable economic and other realities, and some forecasting based on those probabilities has been done. Keeping in mind that demand is based on need with funding available to pay for the needed experts, we can examine some of the forecasts of probable requirements for faculty, and for scientists and engineers with similar educational requirements for research and other functions.

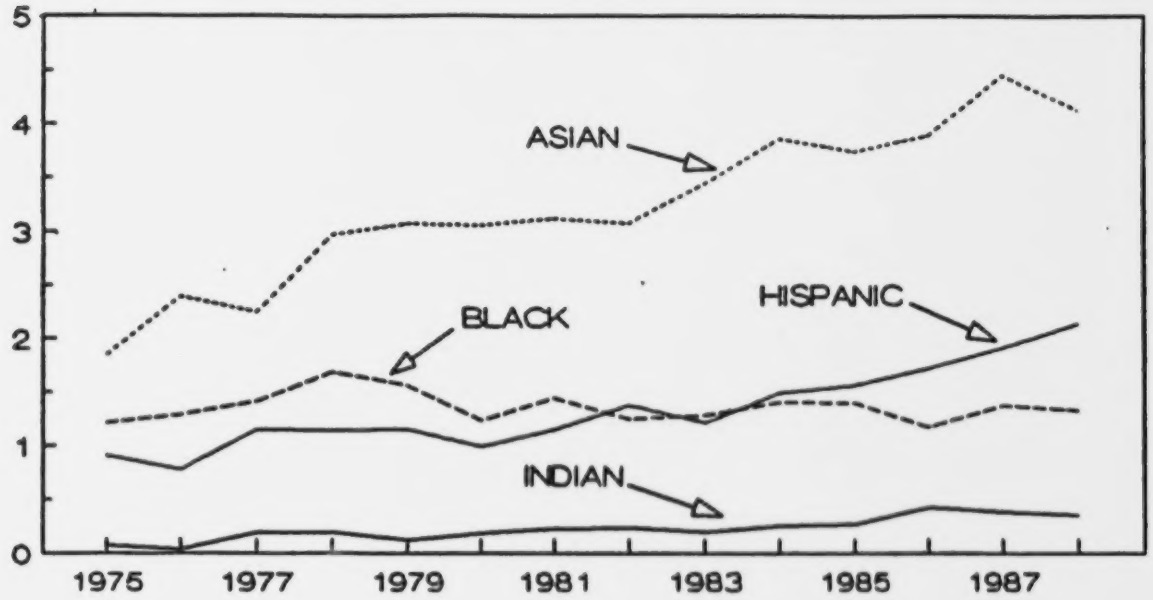

Figure 18. Percent of Natural Science and Engineering Doctorates awarded to American Minorities, 1975-1988. Data Source: National Research Council, **Summary Report 1975** through **1988: Doctorate Recipients from United States Universities**

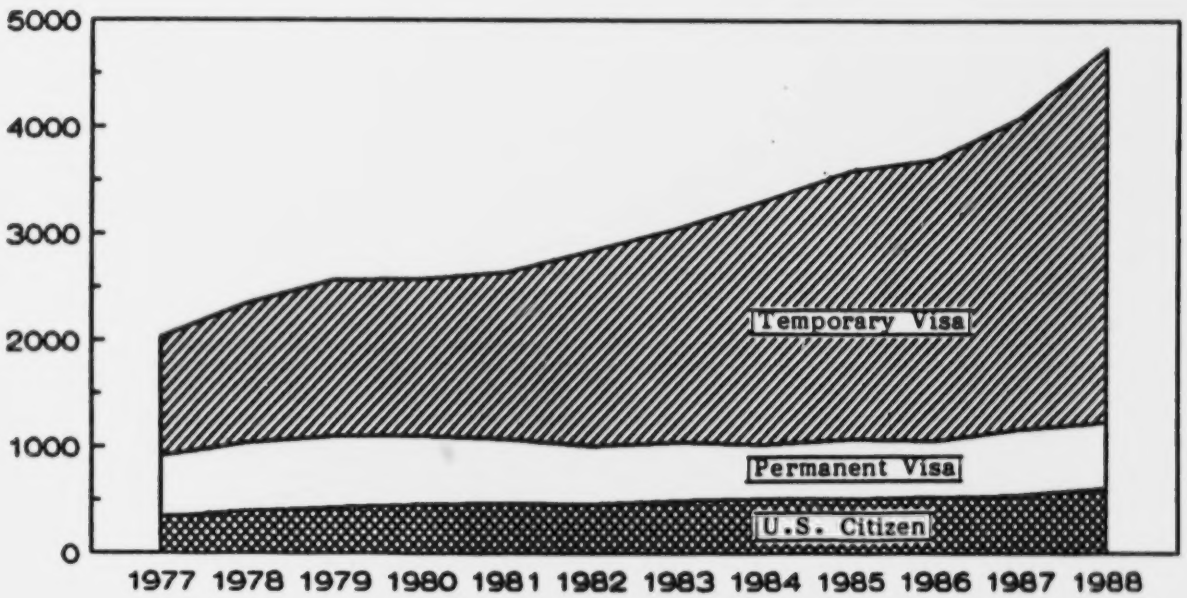

Figure 19. Citizenship and Visa Status of Asian PhD Recipients from U.S. Universities, 1977-1988. Data Source: Data Source: National Research Council, **Summary Report 1975** through **1988: Doctorate Recipientds from United States Universities**

It is uncertain whether more American engineering PhDs are now available for faculty positions than was true in previous years. Although we do know that the number of American citizens earning engineering doctorates has increased each year since 1984, data are lacking to indicate what proportion of the American PhDs contemplate academic appointments. Among 1988 graduates, 24 percent indicated plans for employment by an academic institution, and 21 percent expected to teach as a primary activity (NRC 1989). However, we cannot tell what proportion of that group is American, or even what proportion may be foreign citizens planning to take U.S. faculty positions.

Other surveys also indicate various degrees of difficulty in faculty hiring in engineering and in related fields. A survey by the American Council on Education (El Khawas 1988) found that chief academic officers already report faculty shortages in certain fields, including particularly computer science, business, mathematics, health professions and engineering (fig. 20). Looking forward over the next five years, these academic officers see some easing of the shortage in some of these fields and an enlargement in others, including engineering.

Although only 21 percent of the responding institutions report present difficulty in recruiting engineering faculty, the proportion increases over the next five years to 24 percent. The fact that engineering is indicated by higher education administrations as having less shortage than fields such as computer science and business is a reflection of the makeup of the survey population, including as it did all types of academic institutions, many of which do not have engineering schools, but do have large faculty needs in computer science, for example.

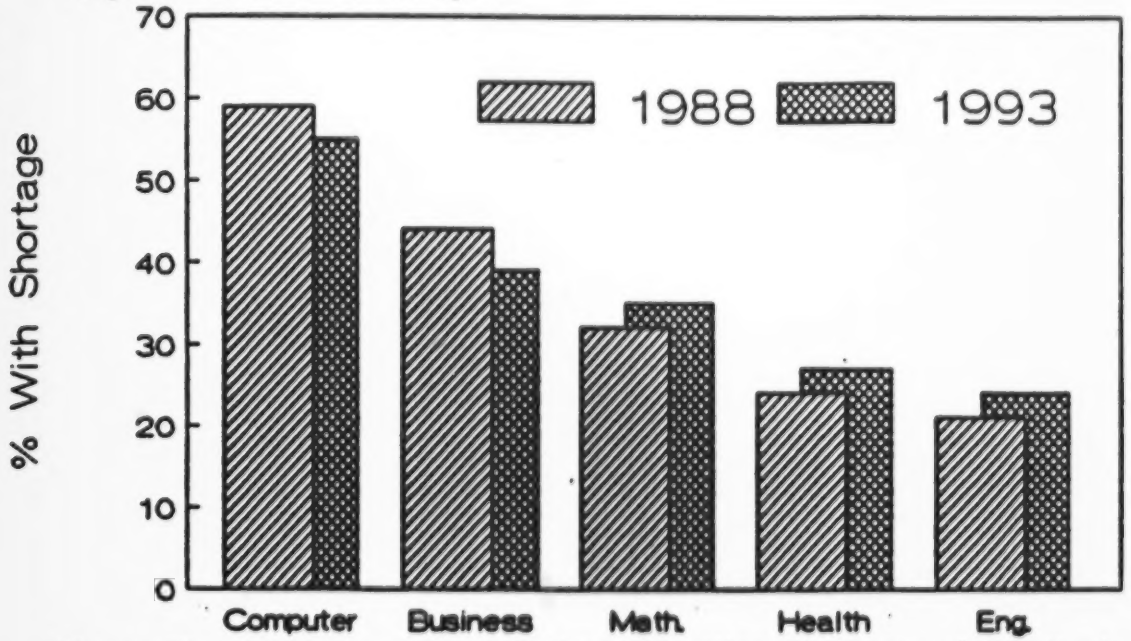

Figure 20. Percentage of Institutions Reporting Shortages of Faculty in 1988 and shortage anticipated in 1993. Data Source: American Council on Education, **Campus Trends, 1988.**

Examining the engineering shortage by type of institution shows extensive problems in faculty recruitment at PhD-granting institutions, where most engineering schools are located, but not much at two year schools (fig. 21).

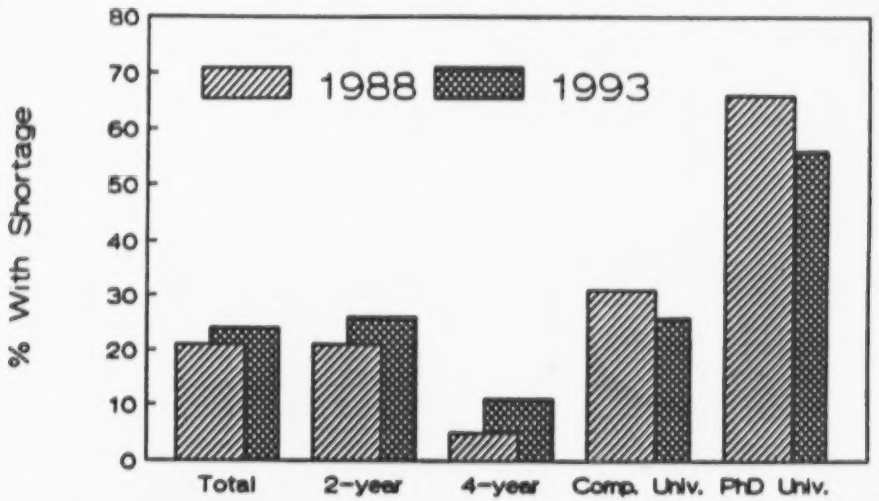

Figure 21. Percentage of Institutions Reporting Shortages of Engineering Faculty in 1988 and shortage anticipated in 1993, by Type of Institution. Data Source: American Council on Education, **Campus Trends, 1988.**

There are some apparently chronic shortages of engineering and computer science faculty now, but the 1990s will be a special time for faculty demand. Competition for a dwindling pool of Americans trained to this level is bound to increase because of the very substantial portion of science and engineering faculty who will reach age 65 during that decade. There is no question that fewer engineering faculty members in the 1990s will be native born Americans than has been true even in recent years. In 1986, 16 percent of full time faculty in all science and engineering had received their baccalaureates at foreign institutions, ranging from two percent in psychology to almost 20 percent in computer sciences. In engineering, one fourth of full time faculty in mechanical and civil engineering and one fifth of those in chemical engineering had foreign baccalaureates. The figures would be considerably higher if foreign born faculty with U.S. baccalaureates were included (Falk, 1989).

A new study of coming faculty shortages in the humanities and social sciences (Bowen and Sosa 1989) projects faculty shortages through 2012, with the worst of the problem occurring from 1997-2007. Faculty openings will grow rapidly beginning in the mid-1990s, both because academically employed scientists and engineers are markedly older than their cohorts in other employment settings, and because student enrollments will rise. But authors Bowen and Sosa found that the largest shortfalls will result not from retirements, but from growth in student enrollments after 1996, when the college age population starts to increase again, as shown in figure 1 by the increasing number of 18 year olds after 1996.

In the 1987-92 period, this study finds 1.6 candidates available for each open teaching position, including those in the humanities. But by 1997-2002,

the figure will drop to .83 for each job, with 30,934 new faculty members to fill an estimated 37,091 positions. In 1997-2002, the candidates-to-jobs ratio would be 0.71 in the humanities and social sciences, 0.80 in mathematics and the physical sciences, and 1.13 in the biological sciences and psychology. Figure 22 shows the difference between projected supply and demand in each five year increment in the three broad field groups used in the study.

These researchers also forecast considerably higher shortages in the humanities and social sciences than in the mathematical and physical sciences; and do not foresee any shortages at all in the biological or behavioral sciences.

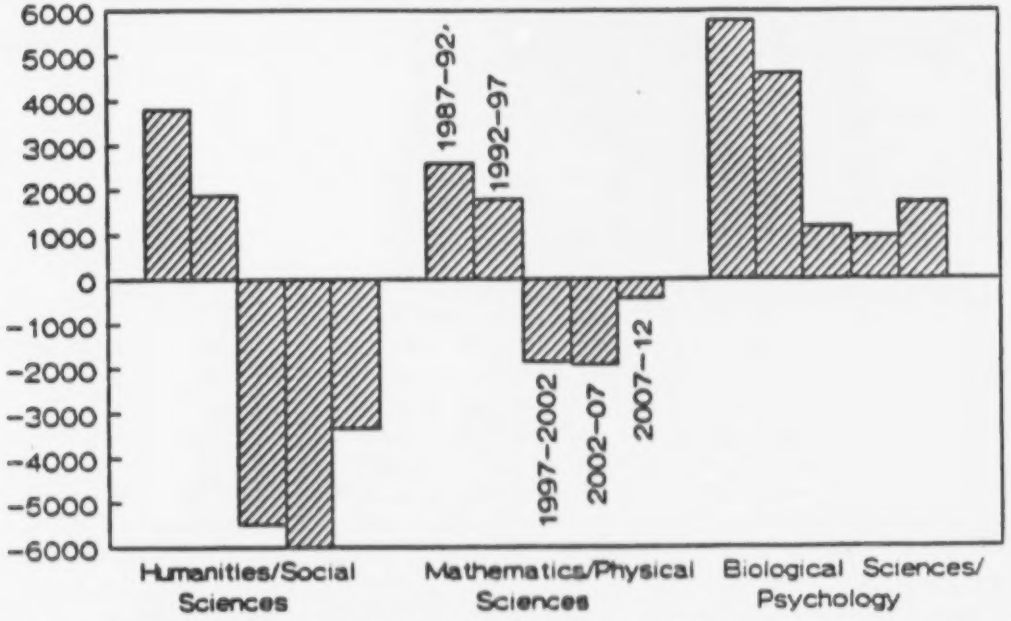

Figure 9. Projected Supply of Faculty Applicants Minus Demand for Faculty, 1987-2012, by Broad Field Groups. Data Source: Bowen and Sosa, **Prospects for Faculty in the Arts and Sciences: A Study of Factors Affecting Demand and Supply 1987-2012**, 1989

Labor market conditions and steady enrollments during the 1970s resulted in relatively few faculty openings, and the number of doctorates awarded to American citizens declined. There also were significant shifts in degree fields among doctorate recipients, and a larger fraction of doctoral recipients chose or were pushed toward non-academic careers. Between 1977 and 1987, the percentage of all holders of doctorates employed by colleges and universities declined significantly in every arts and sciences field except earth sciences.

The coming decades present a quite different pattern. Beginning by at least 1997, faculty demand is expected to exceed supply by substantial amounts and across most fields, and none of a variety of market adjustments, including cutting retirement rates by half, would reduce the shortage substantially. For at least a decade after 1997, Bowen and Sosa projections imply that there will be only seven candidates for every ten positions in the arts and sciences. Engineering has shown significant shortages since 1980.

While all forecasts include many uncertain elements, there is considerable evidence to indicate potential difficulties ahead unless there is a significant change in the current trends.

There is no question that science and engineering faculty slots, as well as those in the humanities and probably the professions can be filled. There is only a question of the characteristics of the persons who will fill them and whether necessary substitutions will dilute or otherwise change the quality of American faculty. If the ideal model being sought is not available, then compromises will be made, perhaps by hiring even more foreign citizens, or by hiring more faculty without doctorates, or by some other method.

Increasing or even continuing present heavy reliance on foreign graduates is dangerous for several reasons, as discussed earlier. If we do need more doctoral scientists and engineers than are available, we cannot necessarily assume that they can be supplied by increasing the opportunities for foreign graduates to become a part of the American labor force.

Replacement needs are increasing for all natural scientists and engineers, not only in academe but in all sectors, as shown in figure 23 (NSF 1989 Working Draft). New academic demand and growth in replacement needs both begin to increase in the second half of the 1990s, as the number of college age Americans starts to rise again and retirement of present faculty increases. Even if half of all foreign graduates continue to be absorbed into the American labor force, which does not seem very likely, the supply of new doctorates in these fields is expected to fall short of demand.

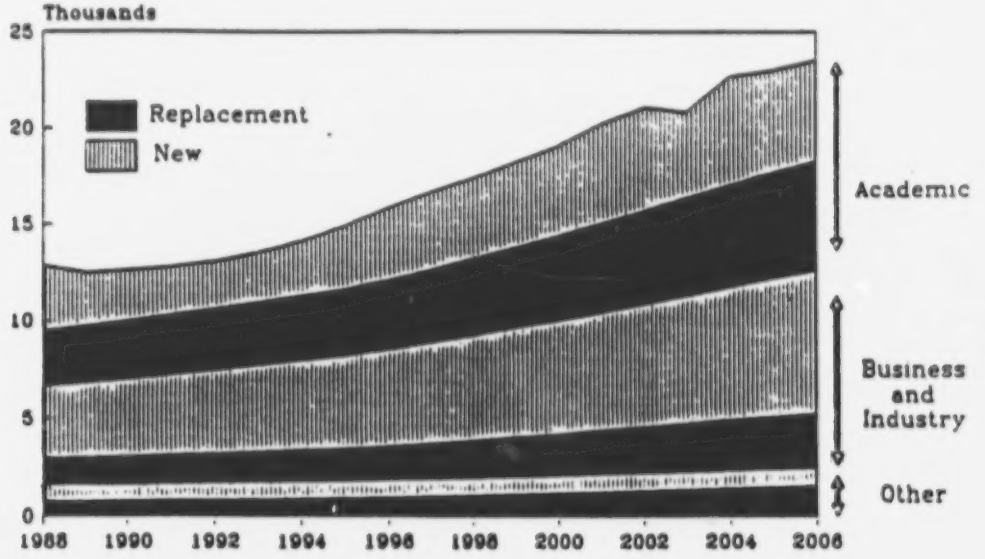

Figure 23. Growth of Potential Ph.D. Jobs at Current Salary Levels Showing New and Replacement Jobs in Three Sectors. Source: National Science Foundation, STIA Working Draft

Where will we find enough faculty members who are Americans; or who can teach American students effectively, particularly women and minority

students? Because if we don't attract more women and minority students, we may be unable to produce the number of American graduates at any level that will be needed. Without more women students, there are not likely to be more women faculty and vice versa.

Assuming that 40% of PhD graduates in engineering might be available for academic jobs, (a proportion two thirds higher than was true among all engineering PhD graduates of 1988), present rates of production of female and minority PhDs would allow each engineering school in the country to hire one American black, Hispanic or American Indian every 19 years, and one non-minority woman every 8 years! Thus, unless present patterns are changed, neither women nor minorities can be expected to make up any potential shortage in engineering.

Except in the social sciences, fields with the oldest faculties generally include few women in faculty ranks. Physicists employed in academic institutions include only 4.4 percent women; with 60 percent being 45 or older and 23 percent 55 or older. In chemistry, with 12.8 percent women, 60 percent are 45 or older, and 26 percent will be 65 or older by 1997. In the life sciences, on the other hand, where women make up 22.1 percent of those employed in academe, only 47 percent were 45 or more in 1987 and only 20 percent were over age 54. The proportions are similar in psychology, where women are 31 percent of academic employment, and the proportions over 44 and 54 were 48 and 22 percent.

The social sciences are somewhat different. Among faculty in economics, which includes only ten percent women, only 51 percent are above 44 and 26 percent above 55; while among sociologists and anthropologists, including 30 percent women, 61 percent are over 44 and 23 percent are over 54.

There is no question that the number of faculty openings will increase after 1995, although opinion differs as to how much. The Bureau of Labor Statistics, in its projections of employment change from 1988 to 2000, forecasts an increase of three to seven percent in college and university faculty by 2000 (Sylvestri and Lukasiewicz, 1989). This increase of 23,000 to 62,000 faculty members does not include the numbers needed to replace present faculty.

Bowen and Sosa note the need to increase overall production of new Ph.D.s by two thirds, including a doubling of current numbers. Further, these increases need to occur at the same time that the number of 30-year-olds, the typical age for earning the PhD, is moving steadily downward from its peak in 1988 to its lowest point in 2005 (see figure 1).

To assure a quality American faculty over the next two decades, policy changes are required to provide resources and incentives to increase the supply of new Ph.D.s and reduce the time required to earn the degree. The federal percentage of aid through fellowships and traineeships was only half as large in 1987 as in 1967. A renewed commitment to graduate education will be essential to provide faculty for tomorrow's undergraduate students.

Time is running out. Now is the last possible moment to begin to recruit American students, and particularly women and minority students to prepare for faculty careers in the 1990s and beyond.

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